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PIEZOELECTRIC PUNCH DEVICE
[Atsuden'shiki sen'ko sochi]

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Specification

/553*

1. Name of this invention

Piezoelectric punch device

2. Claims

[1] Piezoelectric punch device equipped with a liquid pressure system having a piezoelectric element as a drive source, punch pin operated by a fluid pressed by this liquid pressure system, and punch die positioned to face against the punch pin sharing the same axis to punch through a processing object by receiving the pin synchronous to the pin movement.

[2] In Claim 1, the device is equipped with a protruded single flow type punch pin containing plural planes with a blade containing a positive shearing angle where the shearing angle is designed to regularly increase in several steps.

3. Detailed explanation of this invention

[Industrial Field]

This invention pertains to a piezoelectric punch device using a piezoelectric element as its drive source.

[Conventional Technology]

With a punch system installed in various kinds of card processing devices (e.g., magnetic card type public telephone,

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paper card puncher), a drive system consisting of a solenoid coil is conventionally utilized as the drive source of the punch pin. However, this type of drive source containing a solenoid coil driven by electric currents consumes a high volume of power and requires complex structure and a bulky structural frame. Furthermore, the use of solenoid coil limits the design of the device. For those reasons, it is hard to produce compact and low power-consumption card processing devices with the conventional method.

[Summary of this Invention]

This invention was developed to solve said problems by providing a new type of piezoelectric punch device that uses a punch pin drive system driven by electric fields, requiring low power consumption, and is simply structured so as to be easily made into a compact and thin device capable of reducing power consumption as well as production cost. Also, this invention /554 provides a new device which can improve the energy conversion efficiency by combining a protrusion type single flow punch pin having a punching strength suited to the displacement and force of the piezoelectric element.

[Operational example]

The following explains the operational example of this invention.

Figures 1 - 3 are diagrams of a piezoelectric punch device based on this invention used in the operational example. In those figures, item **1** designates a laminate type piezoelectric element used as a drive source for operating a punch pin **2** of the piezoelectric punch device. This laminate type piezoelectric element **1** is configured by laminating multiple (n pieces) piezoelectric plates **1-1** - **1-n** while placing an electrode layer **3** (3a, 3b) between each of the piezoelectric plates. Also, said electrode layers **3a, 3b** are separately polarized and taken out to be connected a pair of external electrodes **4a**, **4b**. By impressing an electric voltage between those external electrodes **4a**, **4b**, piezoelectric plates **1-1** - **1-a** produce the same displacement (extension or contraction) and operate (extend or contract) a laminated piezoelectric element **1** according to the polarity of the impressed voltage and voltage value. That is, this laminate type piezoelectric element **1** generates an electric voltage when force is given, and produces a force/displacement when an electric voltage is given. Considering such mechanism, this type of device is used as an actuator.

Said laminate type dielectric element **1** has a displacement-force characteristic as shown in Fig. 2, where the force **F** decreases proportional to the increase of displacement **S**. The chart in this figure is the result of laminate type piezoelectric

element **1** containing 100 pieces of piezoelectric plates (width = 10 x 10 mm, thickness = 0.25 mm). For example, the displacement generating 10 Kg of force is approximately 40 µm.

Punching force for punching a hole (1.2 diameter) through a 0.3 mm thick plastic (e.g., polyester) card is approximately 0.5 Kg. In this case, the displacement of punch pin **2** must be at least 2 mm considering the allowance for a punch die system. Therefore, each part should be designed to satisfy those conditions.

Figure 3 is a diagram of a piezoelectric punch device based on this invention. In the figure, item **10** is a liquid pressure system using said laminate type piezoelectric element **1** as its drive source. This system **10** contains a casing **11** carrying said laminated piezoelectric element **1** at one end side and also has a piston **12** operated in the forward/backward directions by the dielectric element **1**, and first and second fluid pressure chambers **16A**, **16B** filled with liquid **17** receiving a pressure. The first fluid pressure chamber **16A** is configured in such a way that said piston **12** is contracted at one end side while being connected to the second chamber **16B** via an exhaust valve **14** at the other end side. A reservoir tank **18** reserving liquid **17** via an absorption valve **13** and absorption pipe **19** is connected to the first fluid pressure chamber **16A**. The absorption valve **13** only opens to the first fluid pressure chamber **16A** from the reservoir tank **18**, and

the absorption valve **14** only opens to the second fluid pressure chamber **16B** from the first fluid pressure chamber **16A**.

The second fluid pressure chamber **16B** is connected via the reservoir tank **18** and exhaust pipe **19b** while its opening area is opened/closed by a bimorph type piezoelectric element **15**. This piezoelectric element **15** is operated by a control signal (see Fig. 8) transmitted from the controller **20** along with said laminate type piezoelectric element **1** (described later). By opening such area, the liquid **17** in the second fluid pressure chamber **16B** flows into the reservoir tank **18**.

The rear end of the punch pin **2** is supported at one part of the second fluid pressure chamber **16B**, allowing the insertion movements of the pin **2**. This punch pin **2** engages to the hole **21a** of the punch die **21** positioned to face against the tip of the pin **2** when pressed by the liquid pressure of the second fluid pressure /555 chamber **16B**, being pushed out in the lower direction in the figure to make a hole through an object card (not shown in the figure). Item **22** in the figure is a returnable spring of the punch pin **2**. Also, piston **12** and rear end of the punch pin **2** are supported to freely slide in and out from the first and second fluid pressure chambers **16A**, **16B** for sealing the liquid **17**.

Furthermore, the controller **20** contains a drive circuit which sequentially operates the laminate type piezoelectric element **1** and bimorph type piezoelectric element **15** at a selected interval by impressing a specific voltage to terminals **V1** - **V4**.

That is, the piezoelectric element **1** is connected to terminals **V1**, **V2** of the controller **20**, to which voltages **-Vl**, **0**, **+VL** are impressed. When the condition shown in Part (A) of Fig. 4 is used as its standard, if impressed voltages are V1 = -VL, V2 = 0, as shown in Part (B) of the figure, the element contracts in the direction of arrow "a" to produce displacement **-δ VL**. Also, by impressing voltages V1 = 0, V2 = +VL, as shown in Part (C) of the figure, the element extends in the direction of arrow "b" to produce displacement **+δ VL**. By repeating this process, the element **1** can provide extension/contraction movements.

On the other hand, the bimorph type piezoelectric element **15** is connected to terminals **V3**, **V4** of the controller **20**, to which voltage **-VB**, **0**, or **+VB** is impressed. When the condition shown in Part (A) of Fig. 5 (V3 = 0, V4 = 0) is used as its standard, and voltages V3 = -VB, V4 = 0 are impressed, as shown in Part (B) of the figure, this bimorph dielectric element **15** warps in the direction of arrow "c", and opens, connecting the second fluid pressure chamber **16B** to the reservour tank **18**.

Note that the operational circuit of the controller **20** is not particularly limited as long as it can create a pulse wave from the signal transmission circuit in order to increase the voltage by pulse-transmission.

The piezoelectric punch device configured in this manner performs punching and recovery operations as shown in (A) - (D) of Fig. 6 and (A) - (B) of Fig. 7.

That is, Part (A) of Fig. 6 shows the initial condition of the device based on this invention, in which each terminal **V1** - **V4** of the controller **20** is set to zero, making the laminate type and vimorph type piezoelectric elements **1**, **15** non-operational. Also, absorption valve **13** and exhaust valve **14** are closed. Therefore, the reservoir tank **18** and first/second fluid pressure chambers **16A**, **16B** are independently operated, thereby not providing the liquid flow **17**. Furthermore, protruded single flow punch pin **2** is pressed against a part of the casing **11** by a recovery spring **22**, allowing the part to functioning a stopper as well. This condition is equivalent to Step 1 in Fig. 8.

Part (B) of the figure shows the second step II, where the controller **20** impresses voltages V1 = -VL, V2 = 0 to the terminals **V1**, **V2** of the laminate type dielectric element **1** to contract the piezoelectric element **1** in the direction of arrow "a", making the piston **12** displaced for -δ **VL** to the left in the figure. In this

situation, the absorption valve **13** opens to let a specific amount of liquid **17** flow from the reservour tank **18** into the first fluid pressure chamber **16A**.

Part (C) of the figure shows the third step III, where the controller **20** impresses voltages V1 = 0, V2 = +VL to the terminals **V1**, **V2** of the laminate type dielectric element **1** to extend the piezoelectric element **1** in the direction of arrow "b", displacing the piston **12** for +δ VL to the right in the figure. In this situation, the absorption valve **13** closes while opening the exhaust valve **14** to let a specific amount of liquid **17** flow from the first fluid pressure chamber **16A** into the second fluid pressure chamber **16B**. With this fluid movement, the punch pin **2** is pushed to the punch die **21** according to the Pascal's theory.

Part (D) of the figure also shows the second step II shown in Part (B), where the controller **20** impresses voltages V1 = -VL, V2 = 0 to terminals **V1**, **V2** of the laminate type dielectric element **1** to contract the piezoelectric element **1** in the direction of arrow "a", displacing the piston **12** for -δ VL to the left in the figure. In this situation, the absorption valve **13** opens to let a specific amount of liquid **17** flow from the reservour tank **18** into the first fluid pressure chamber **16A**. According to the second step II 1 in Part (B) of Fig. 6, Part (D) of Fig. 6 shows the second step II 2./556

By alternately repeating second steps II 1, II 2, II 3, II 4,...II n and third steps III 1, III 2, III 3, III 4, ...III n, the punching operation completes when the punch pin **2** is sufficiently inserted into the hole **21a** of the punch die (i.e., third step III n shown in Part (C) of Fig. 6).

Part (A) of Fig. 7 shows the state, the fourth step (phase IV), when the previous step has completed. At this time, the liquid **17** flowed into the first pressure chamber **16A** from the reserve tank **18** has completely sent into the second fluid pressure chamber **16B**.

Part (B) of the figure shows the condition of fifth step V when the punch pin **2** is returning to the initial state by the returning spring **22**. At this time, voltages V3 = -VB, V4 = 0 are impressed to the vimorph type piezoelectric element **15** from the controller **20**, causing the element **15** to warp. As a result, the liquid **17** continuously flows from the second fluid pressure chamber **16B** into the reservour tank **18**.

By alternately repeating second steps IV 1, IV 2, IV 3, IV 4,...IV n and fifth steps V 1, V 2, V 3, V 4, ...V n, the punching operation returns to the initial phase of the first step I shown in Part (A) of Fig. 6.

Figure 8 shows the condition when operational voltage is impressed to terminals **V1** - **V4** of the controller **20** during the

initial phase described above (first step I), punching state (second steps II 1, II 2, II 3,...II n and third steps III 1, III 2, III 3,...III n), and recovery state (fourth steps IV 1, IV 2, IV 3,..IV n and fifth steps V1, V2, V3,...V n).

Also, as shown in Fig. 9, completion of punching and recovery of the punch pin **2** can be easily detected using detectors **24a**, **24b** detecting the upper/lower limits of the tip **23a** of the lever **23** formed on the punch pin **2**.

Parts (A) and (B) of Fig. 10 show diagrams of the protrusion type single flow blade **30** of the punch pin **2** having appropriate strength for punching a hole with an optimal displacement-force characteristic for the piezoelectric element used as a driving source. Parts (A) and (B) of Fig. 11 are charts showing the relation between such force and blade. With such appropriate combination of force and blade shape, the energy conversion efficiency of the overall device can be improved.

That is, with the method based on this invention, the protruding single flow blade part **30** of the punch pin **2** is specifically designed so that the blade has multiple (first and second) planes **30A**, **30B** whose blade angles are made into positive shearing angles **01**, **02** which are designed to increase in regularity.

The following explains this structure in detail:

Said protruding single flow blade **30** consists of a first plane having a shearing angle **01** and second plane having a shearing angle **02** which is greater than the first angle (the entire blade shearing is h). This type of blade **30** has the following benefit compared with the conventional blade **2a** of a single flow pinch pin **2** shown with a dotted broken line in Part (A) of Fig. 10:

The shearing angle of the blade **2a** is θ having a relation of 01 < 0 < 02. The characteristic of the punching-hole power of the blade **30** based on this invention is shown with a line in Fig. 11. Also, the characteristic of the punching-hole power of the blade **2a** of the punch pin **2** having equal shearing angles **h** is shown with a broken line in the figure. Item **S** designates the punch pin displacement, and **F2** designates the required punching-hole power.

As shown in Fig. 11, the punching-hole characteristic of the blade based on this invention provides higher first peak **P1** and lower second peak **P2** compared with those of the blade **2a** of regular punch pin **2**. That is, by designing the punch pin **2** as a protruded single flow shape, the punching-hole power can be adapted to the force-displacement characteristic of the laminate type piezoelectric element 1 based on this invention.

This benefit can be explained by the following reasons: /557

According to the research on punch-die systems, the greater the shearing angle, the smaller the reduction of maximum punching power. Parts (A) and (B) in Fig. 12 show typical examples of blade **2a** characteristic of a single flow type punch pin **2**, exhibiting two peaks **P1**, **P2** on the punching force characteristic curve. The first peak **P1** occurs when the tip **2a** of the punch pin touches a paper or plastic card, and the second peak **P2** occurs immediately before the card-penetration by the rear end of the punch pin **2**. Those two peaks present approximately the same values. Also, the broken line in the figure shows the characteristic when the shearing angle is 0' (>0). This result shows that, although the displacement needing for punching increases due to increased shearing angle, two peak values of the punching power decrease.

The force-displacement characteristic of the laminate type piezoelectric element **1** decreases along with the increasing displacement as shown in Fig. 2. Therefore, to efficiently take advantage of this characteristic, punch pin **2** must have an optimal punching power characteristic for providing force-displacements. That is, the punch pin **2** should present a high first peak and low second peak on the punching force characteristic curve compared with that of the blade surface **2a** of the single flow punch pin **2**. Such punch pin is the protrusion type single flow blade **30** shown in Fig. 10.

Note that this invention is not limited to the example described above, and shape/structure of each part may be freely modified.

[Effectiveness of this Invention]

As explained above, with the piezoelectric punching device based on this invention, a laminate type piezoelectric element is operated by electric fields with minimal power consumption as the drive source of punch pin (punching means), and a protrusion type single flow punch pin is operated by the force produced by this piezoelectric element via a fluid pressure transmission system. Therefore, although simply structured, the overall size and thickness as well as required power consumption can be reduced. Also, by utilizing a protrusion type single flow punch pin having a punching characteristic optimal to the displacement-force characteristic of the piezoelectric element, energy conversion efficiency of the overall system can be drastically improved.

4. Simple Explanation of the Figures

Figures shown below are related to one operational example of the device based on this invention. Figure 1 is a diagram showing the laminate type piezoelectric element based on this invention. Figure 2 is a chart showing the force-displacement characteristic of this piezoelectric punching device. Figure 3 is a diagram showing the device based on this invention. Parts (A) - (C) of

Figure 4 are charts explaining the operation of the laminate type piezoelectric element. Parts (A) - (B) in Figure 5 are charts explaining the operation of the vimorph type piezoelectric element. Parts (A) - (D) of Figure 6 show the operational charts during punching using the device based on this invention. Parts (A) - (B) in Figure 7 show the same operational chart representing the recovery time. Figure 8 is a time chart of terminals V1 - V4 showing the condition of each piezoelectric element when a control signal is impressed. Figure 9 is a diagram showing one example of punch pin position detection. Parts (A) - (B) in Figure 10 are side surface and cross-sectional diagrams of the punch pin tip area of the protrusion type single flow punch pin based on this invention. Figure 11 is a characteristic chart of the punching power. Parts (A) - (B) of Figure 12 is a diagram of side surface of conventional single flow punch pin and a characteristic chart of the punching force.

1...Laminate type piezoelectric element; 1-1 - 1-n...Piezoelectric plate; 2...Punch pin; 3 (3a, 3b)...Electrode layer; 4 (4a, 4b)...External electrode; 10...Liquid pressure system; 11...Casing; 12...Piston; 13...Suction valve; 14...Exhaust valve; 16...Vimorph type piezoelectric element; 16A, 16B...First and second liquid pressure chamber; 17...Fluid; 18...Reservoir tank; 19a, 19b...Suction/exhaust pipe; 20...Controller; 21...Punch

die; 22...Recovery spring; 30...Protrusion type single flow blade;

30A, 30B...First/second blade

[Figure 2]
F...Force;
S...Displacement.

[Figure 11]
Fs...Punching force;
S...Displacement.

[Figure 12 (B)]
Fs...Punching force;
S...Displacement.

Fig. 1

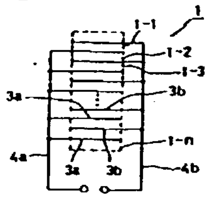

Fig.3

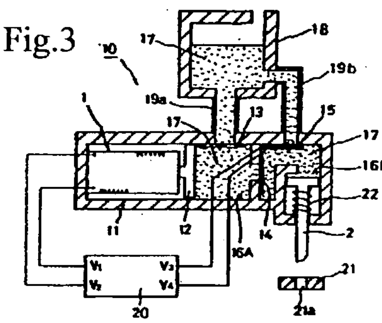

Fig. 2

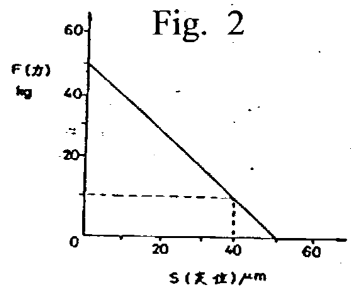

Fig. 4

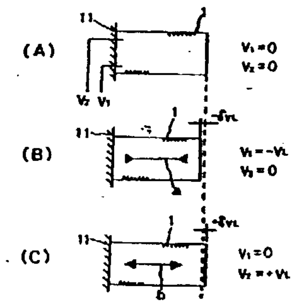

Fig. 5

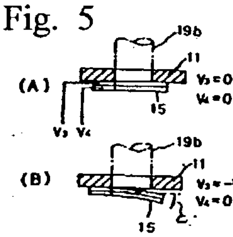

Fig. 6 (A)

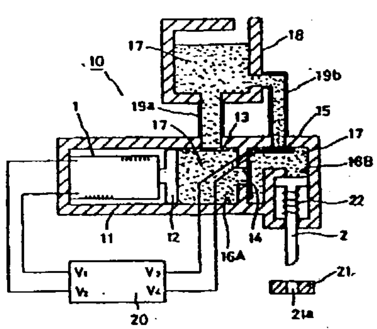

Fig. 6 (C)

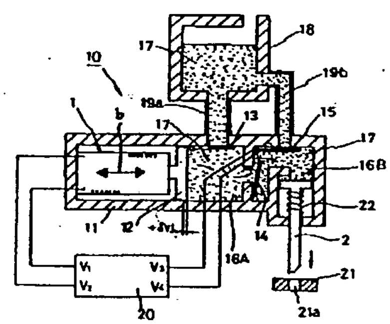

Fig. 6 (B)

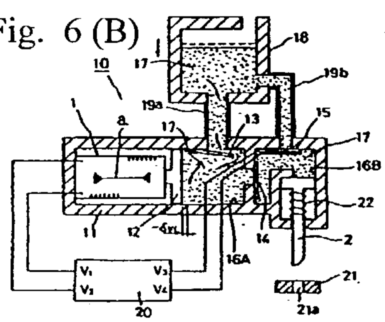

Fig. 6 (D)

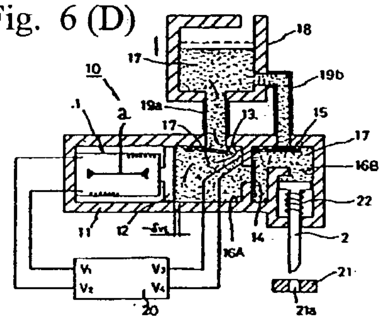

Fig. 7 (A)

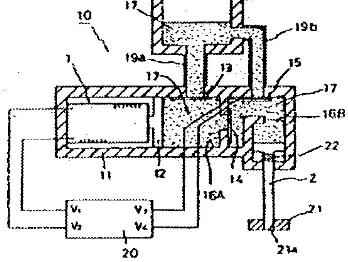

Fig. 7 (B)

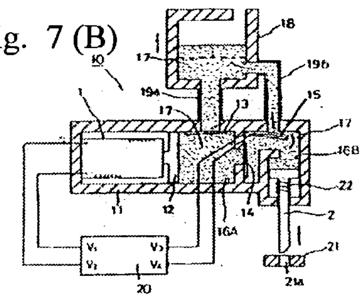

Fig. 8

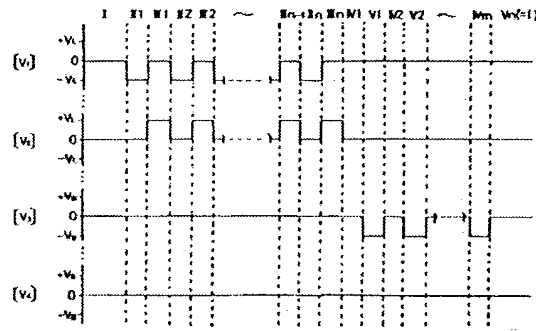

Fig. 9

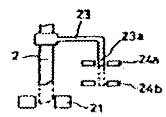

Fig. 10

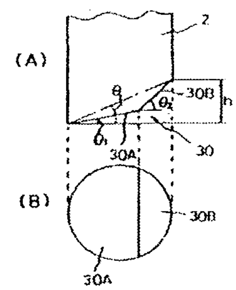

Fig. 11

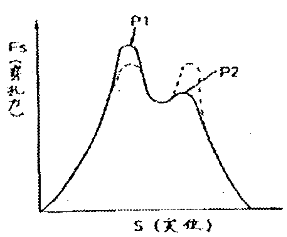

Fig. 12 (A)

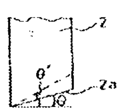

Fig. 12 (B)